Langmuir Turbulence

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LONG-TERM GOALS

We aim to understand the dynamics of the upper ocean boundary layer and use this understanding to improve the parameterizations used in operational models.

OBJECTIVES

We aim to make definitive experimental tests of the hypothesis that Langmuir Turbulence, specifically the equations of motion with the addition of the Craik-Leibovich vortex force and advection by the surface wave Stokes drift, can accurately describe turbulence in the upper ocean boundary layer under conditions of wind and wave forcing. We anticipate that this hypothesis will need to be modified to include the effects of surface wave breaking and aim to understand how to reformulate it most effectively. We aim to use this knowledge to refine parameterizations of upper ocean turbulence, to validate them through model-data comparisons and transition them into high-resolution regional and global ocean models.

APPROACH

This work will be conducted as part of the Waves, Langmuir Cells and the Upper Ocean Boundary Layer Departmental Research Initiative. The details of this program have not yet been finalized. We expect to work with the larger DRI experimental team to measure the properties of upper ocean turbulence using Lagrangian floats deployed near the research platform FLIP. Measurements on FLIP will define the air-sea fluxes, the surface wave properties and the surface manifestations of boundary layer turbulence. Measurements from the floats will define the subsurface turbulence properties. A new innovation for this program will be the use of Doppler current profilers on the floats so that the full suite of temperature, salinity and velocity measurements can be made from the floats. Large Eddy Simulations and Second Order Closure theory will be used to model the combined FLIP and float datasets. A more definitive experimental and analysis plan is expected to be formulated at DRI meetings in late 2015.

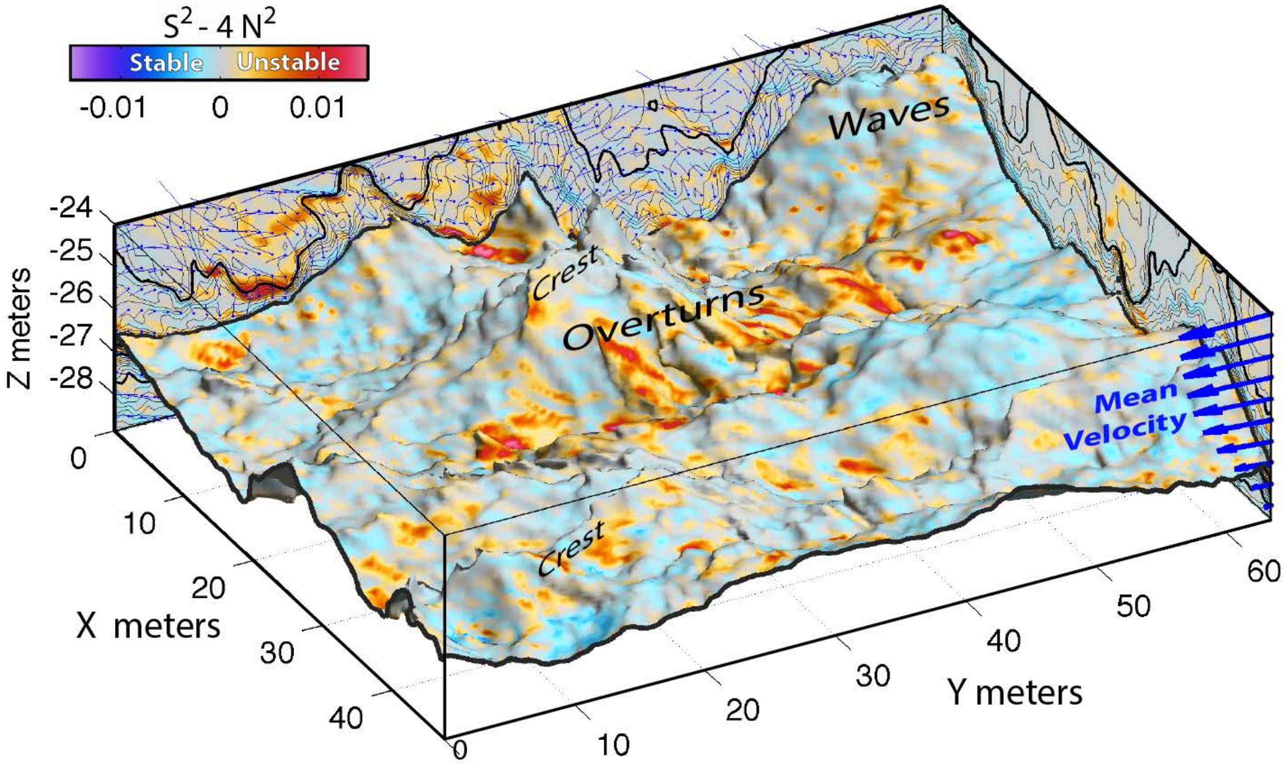

Fig. 1. Visualization of a simulated isopycnal within an entraining TL. Color is Shear^2−4N^2; reds are unstable to shear instability; blues are stable. An animation of this surface can be viewed at http://faculty.washington.edu/shcher/TL/IsoBreakingSurfaceAll.mov. Visually, the isopycnal surface resembles a breaking sea surface under strong winds, with asymmetric waves and intermittent breaking, especially in the animation. On horizontal scales of 20−50m, wave-like features with vertical displacements of a few meters occasionally sharpen into overturning crests. On smaller ~10m horizontal scales, patches of shear instability (red) are associated with meter-scale overturns.

WORK COMPLETED

The basic experimental outline was established at meetings in summer 2014 and 2015. Based on these, we have begun constructing three Lagrangian floats to be used in the 2017 field program. In particular, we conducted a comprehensive study of the new crop of smaller ADCPs that have become available and decided on the Nortek Signature line as most appropriate for float use. We are now testing these units and integrating them into the floats.

A critical component of the Langmuir DRI is improvement of both high resolution LES models and of parameterizations of Langmuir physics in larger scale models. Toward the first goal, we have transitioned our LES modeling to the NCAR LES model code distributed by Peter Sullivan (NCAR). The model physics and origins are largely equivalent to that in previous work, but the new code provides a superior numerical implementation. The NCAR LES employs a more accurate third-order Runge-Kutta time stepping and a dynamic timestep adjustment to meet a fixed Courant–Fredrichs–

Lewy condition. Most importantly, the parallelization of this LES model at NCAR has overcome a significant impediment that has limited other LES studies to lower order subgrid closures (e.g. Smagorinski-type) or less computationally scalable. Using this code, we have begun to simulate the details of the interaction between Langmuir turbulence in the mixed layer and the entraining transition layer at the base of the mixed layer. The figure shows an example of these studies. They show a combination of large-scale sweeps of the surface by the downgoing Langmuir plumes and local shear instabilities within the transition layer, which mix underlying water into the mixed layer.

Toward the second goal, our second moment closure (SMC, *Harcourt 2013, 2015*) of Langmuir turbulence has been implemented within the COAWST version of the ROMS regional ocean model, which includes coupling to the SWAN surface wave model and the WRF atmospheric model. The SMC model has completed coding the new closure into ROMS model subroutines, including new and more accurate 'realizability' constraints on the algebraic closure and stability functions (*Harcourt 2015*). Testing of the SMC of Langmuir turbulence implemented in ROMS, and completed tests in stand-alone column form show these constraints make the model more robust under variable forcing conditions.

RESULTS

None yet.

IMPACT/APPLICATIONS

An improved understanding of the complexities of the coupling between the surface wave field and the upper ocean boundary layer is not only central to improved modeling of the physical environment, but also to predicting other fluxes through the ocean surface such as the transmission of electromagnetic energy. The dynamic details impact the vertical profiles of essentially all physical, chemical, biological, optical and acoustic variables in the upper ocean, and it must be better understood to allow for more effective observation and modeling of the marine environment.

RELATED PROJECTS

The technology for profiling velocity from Lagrangian floats is being pioneered as part of the ASIRI (Air-Sea Interactions in the Northern Indian Ocean) Departmental Research Initiative.

REFERENCES

Ramsey R. Harcourt, 2013: A Second-Moment Closure Model of Langmuir Turbulence. *J. Phys. Oceanogr.*, **43**, 673–697

PUBLICATIONS

Ramsey R. Harcourt, 2015: An Improved Second-Moment Closure Model of Langmuir Turbulence. *J. Phys. Oceanogr.*, **45**, 84–103.